Ooo

19951
098

DYNAMO

ARCHIVE:

PLEASE DO NOT DESTROY

DYNAMIC MODELS TO PREDICT AND SCALE-UP THE IMPACT OF ENVIRONMENTAL CHANGE ON BIOGEOCHEMICAL CYCLING

DYNAMO

Dynamic Models to Predict and Scale-up the Impact of Environmental Change on Biogeochemical Cycling.

Contents;

Participants and key to participating institutes

01 MLURI Macaulay Land Use Research Institute, Craigiebuckler, Aberdeen, AB1 2QJ, UK. *Robert C. Ferrier (co-ordinator)*

02 IH Institute of Hydrology, Wallingford, UK, *Alan Jenkins*, and Institute of Terrestrial Ecology (ITE), Bangor, UK, *Bridget A. Emmett.*

03 SC-DLO Winand Staring Centre, Wageningen, The Netherlands, *Wim de Vries, Gert Jan Reinds, Hans Kros, Bert Jan Groenenberg, Caroline van der Salm.* Catholic University of Nijmegen, *Jan Roelofs*, and the Agricultural University of Wageningen, *Douwe van Dam.*

04 FEA Finnish Environmental Agency, Helsinki, Finland, *Juha Kämäri, Maria Holmberg.* Sub-contract to HAME Regional Environment Centre, Tampere, *Tom Frisk*

05 NIVA Norwegian Institute for Water Research, Oslo, Norway, *Richard F. Wright*, sub-contract to Laboratory of Physical Geography & Soils, University of Amsterdam, Amsterdam, the Netherlands, *Albert Tietema;* and Danish Forest and Landscape Research Institute, Lyngby, Denmark, *Per Gundersen.*

1. Objectives

1.1 The project identifies three main objectives;

-- Apply and evaluate ***dynamic biogeochemical models*** at intensively-studied (and manipulated) ***catchments / large forest stands.***

-- Use these models to ***scale up in space*** from the catchment/stand to the ***regional and continental scale***

-- Use these models to ***scale up in time*** from observations over several years to predict future impacts over decades under ***scenarios of global change, acid deposition and land-use.***

1.2 Issues involved and state of the art;

The focus of DYNAMO is on biogeochemical cycling in terrestrial ecosystems, and the effects on soil, surface and ground water quality in catchments. The development of models is fundamental to our understanding of how systems function. They provide necessary feedback into the planning of future research, by highlighting areas of uncertainty. They also have a pivotal role in the synthesis of the requirements of policy makers and resource managers with those of the research community. Integrated European process based research programmes, have created substantial databases and the utilisation of such data in modelling studies maximises the potential value of this research. However we are facing a fundamentally new challenge, namely, *to integrate dynamic models within a spatial framework, extrapolating our understanding of systems at the individual stand and site level to the larger units of ecotype, landscape, region and continent.*

DYNAMO proposes to assess the consequences of a changed climate, land use and atmospheric composition on soils and surface waters. Special emphasis will therefore be given to the techniques for regionalisation, Regional models move up in scale from calibrations at individual sites, field plots, stands or catchments, and use spatial information. DYNAMO will not involve the collection of new field data, but will involve the merging and harmonising of existing databases. In a first step the enhanced models will be tested and calibrated on data from intensively monitored sites, with special emphasis on sites where large scale manipulation experiments are, or have been, conducted. RAIN sites in Norway, selected CLIMEX, NITREX, EXMAN sites, integrated monitoring sites under UN/ECE as well as other intensively monitored sites in the participating countries. This part will involve all the participating Partners. In a second step, the models will be scaled up in space by using appropriate extrapolation techniques for the various input data. Use will be made of distributions of variables to indicate the uncertainty range in model results using monte carlo simulation techniques. Finally, the enhanced models will be used to assess future scenarios of global change, land use, and atmospheric deposition.

1.3 Compliance with the Workprogramme;

DYNAMO objectives fit closely into Section 1.2.2 (Biosphere processes) of the Workprogramme. In particular the objectives fill several of the research tasks under 1.2.2.1 (Functioning of ecosystems).

Task 1. DYNAMO focuses on biogeochemical cycles and fluxes both within terrestrial ecosystems, and especially between terrestrial and aquatic ecosystems. The models incorporate key ecosystem processes.

Task 2. The models also serve as a book-keeping method for fluxes of water and pollutants into and out of terrestrial and aquatic ecosystems.

Task 5. DYNAMO addresses the single and interactive effects of three major environmental driving factors (global change, acid deposition, land-use change) on biogeochemical cycling and fluxes in natural terrestrial and aquatic ecosystems in Europe.

Task 6. The models and regionalisation techniques applied and developed by DYNAMO are specifically intended to provide tools for assessment of the effects of management actions and pollution control measures on the functioning of natural ecosystems, in particular sensitive natural ecosystems.

Task 7. The scaling up in space is a major emphasis in DYNAMO.

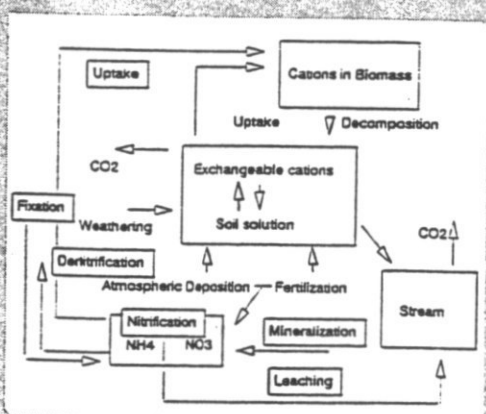
DYNAMO is aimed at fulfilling the activities proposed for TERI (Terrestrial Ecosystem Research Initiative), under thematic area 5 (Integration, up scaling and scenario studies). Several of the sites to be used in DYNAMO are sites of large-scale and multi-project activity. An example is Risdalsheia, at which several ongoing and proposed activities are underway, and which is also a "Large-Scale Facility" under the EU Human Capital and Mobility programme. Thus DYNAMO will take information from several potential TERI sites to scale up in space and time using models along the lines suggested by the TERI programme.

2. Work Content

2.1 Introduction

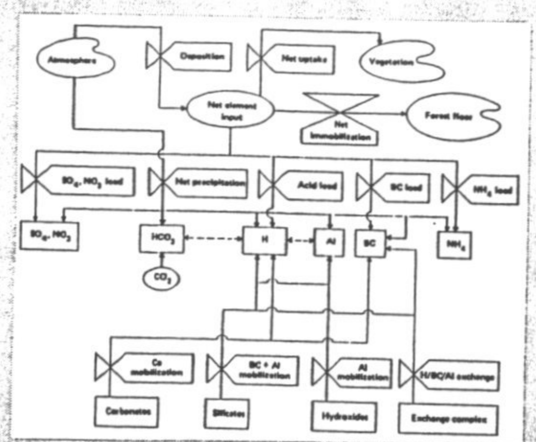
Since many of the most pressing environmental concerns, such as the impact of acidic deposition and climate change, are regional to global in extent, considerable effort has been devoted to the development of methods for extrapolating site-level impact research to regional scales (Kämäri et al. 1989, Hettelingh et al. 1992, Aber et al. 1993). Such regional models have been extensively used for assessing ecological impacts of acidic deposition, and are now needed also for comparable tasks in land use and global change research. Regionalisation techniques are necessary in order to provide meaningful information for evaluating environmental consequences of alternative control strategies of emissions of acidifying air pollutants and greenhouse gases. These methods are based on new kinds of mathematical constructs that are no longer calibrated just for individual sites, field plots, stands or catchments, but can make use of spatial information. Results from synoptic surveys and similar regional studies, have been utilised in various ways by the models. The ability to perform large-scale model simulations has recently been greatly improved by the fast development of tools such as remote sensing techniques, processing technology, and geographic information systems (GIS).

The research groups of this proposal have been intensively involved in the development of such regionalisation techniques for numerical acidification models (De Vries et al. 1994a,b, Jenkins et al. 1990, Posch and Kämäri 1990, Wright et al. 1994), and in related assessments of the regional distributions of critical loads of acidifying deposition for forest soils and surface waters (De Vries et al. 1994c,d, Forsius et al. 1992, Kämäri et al. 1993).



The MAGIC -WAND Model.

Box A; ***MAGIC/MAGIC-WAND:*** The MAGIC model combines a number of key soil chemical processes lumped at the catchment scale to simulate soil and surface water chemistry. MAGIC consists of (i) soil-soil solution equilibria equations in which the chemical composition of soil solution is assumed to be governed by simultaneous equations involving sulphate adsorption, cation exchange, dissolution and precipitation of aluminium and dissolution of inorganic carbon; and (ii) mass balance equations in which the fluxes of major ions to and from the soil and surface waters are assumed to be governed by atmospheric weathering, and loss in runoff. MAGIC-WAND maintains the full sulphur based chemistry of MAGIC and considers two species of inorganic nitrogen, nitrate & ammonium. The primary inputs to the system are considered atmospheric deposition and mineralisation. A specified nitrification rate controls the rate of transfer of ammonium to nitrogen. Provision is also made for other inputs such as fertilisation and nitrogen fixation. Nitrogen losses from the system include denitrification, and the potential runoff flux of inorganic nitrogen in soil and stream water.



The SMART Model

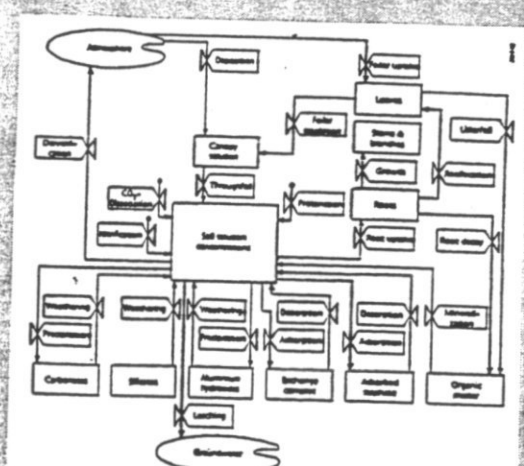
Box B; ***SMART/SMART2*** SMART is a soil acidification model developed to estimate the long-term chemical changes in soil and soilwater in response to changes in atmospheric deposition. The main objective of SMART is to elucidate the temporal and geographical pattern of forest soil acidification. Its major outputs include base saturation, pH, and molar Al/BC ratios, where BC stands for divalent cations. Apart from net uptake and net immobilisation of N, the processes accounted for are restricted to geochemical weathering. State variables depict the quantities of chemical constituents in minerals (carbonates, silicates, oxides, and hydroxides) and on the exchange complex, as well as the ion concentrations in soil solution. Rate variables depict the processes that influence the state variables. This includes the net input of elements (deposition minus net uptake and immobilization) and water (precipitation minus interception and evapotranspiration) and various neutralising reactions (weathering and cation exchange). SMART2 is of intermediate complexity (two soil layers, and monthly time steps) and with a national and continental spatial scale.

For forested sites, acidification models represent a logical starting point also for the analysis of the combined effects of changes in climatic conditions, land use and atmospheric deposition. These models already include descriptions of many of the key processes affected by changes in temperature and hydrological characteristics (e.g. weathering, cation exchange, nutrient uptake by different ecotypes). However, further extensions of the models require the improvement of the physical description of the water balance, and descriptions of organic matter dynamics as a function of temperature, CO_2 and soil water content. Model improvement will form an initial part of the proposed programme of work (see section 2.3.1).

Models of ecosystem response to global change are the most uncertain part of this proposed work. There are simply too few data available at relevant spatial and temporal scales on the effects of increased temperature combined with increased CO_2. Most data are from experiments with single small plants in pots in the laboratory, and scaling up to whole catchments for time scales of years to decades is difficult at best. However, this project will have access to the new data from the CLIMEX experiments, which are one of the few experiments of whole ecosystem effects of increased CO_2 and temperature. As the results from CLIMEX become available, these will be used to improve existing soil/watershed models.

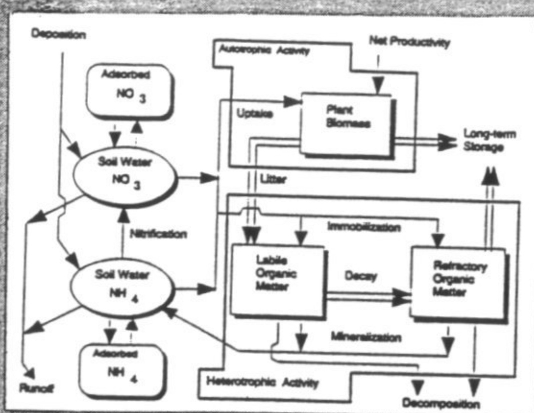
When modelling the response of forest soils and surface waters to atmospheric inputs and changes in the climatic driving variables on a large regional scale, one has to strike a balance between the complexity of the model and the availability of input data. Simple empirical models need only relatively few input data and they generally do not allow to quantification of impacts, since the empirical relationships are derived from present-day conditions. Complex process-oriented models, on the other hand, allow a detailed investigation of the responses of ecosystems at intensively monitored sites, but are not suitable for regionalisation due to the large amount of input data (and computer resources) required.

As a compromise, simple process-oriented models are presently the best available starting point for assessing the impacts of a changing atmospheric composition on soils and surface waters. The process based hydrochemical models to be used and enhanced in this project are MAGIC (Cosby et al. 1985a, 1985b), MAGIC-WAND (Box A), SMART/SMART2 (De Vries et al. 1989, Posch et al. 1993) (Box B) , NUCSAM (Groenenberg et al 1995) (Box C), and MERLIN (Box D). These models were originally developed in part or in whole by the partners involved here in this DYNAMO proposal. SMART/ SMART2 (Simulation Model for Acidification's Regional Trends) is a simple, dynamic process-oriented model based on the charge balance principle. The soil solution chemistry depends solely on the net element input from the atmosphere (deposition minus net uptake minus immobilisation) and the geochemical interactions in the soil (CO_2 equilibria, weathering of carbonates, silicates and aluminium hydroxides, and cation exchange). The solute transport is described by assuming complete mixing of the element input within one homogeneous soil layer with a constant density and a fixed depth. MAGIC (Model of Acidification of Ground water In Catchments) is similar to SMART, but includes a more detailed description of base cation and aluminium chemistry, and organic anions. MAGIC-WAND (MAGIC With Aggregated Nitrogen Dynamics) represents an extension to the MAGIC model to incorporate the major nitrogen fluxes and changes in fluxes through time. The nitrogen dynamics are fully coupled to the existing sulphur driven model (Ferrier et al 1995a). MERLIN (Model of Ecosystem Retention and Loss of Inorganic Nitrogen) (Cosby et al. 1995 a&b) is a further development where all of the nitrogen fluxes described in MAGIC-WAND are incorporated not as input driving variables but are calculated from internal state variables, essentially carbon and nitrogen pools. To date, these models have been used in a number of studies to assess the impact of atmospheric deposition scenarios on soil and surface water chemistry at various sites in Europe (e.g. Jenkins et al. 1990, Wright et al. 1991, Kämäri et al. 1993, Ferrier et al. 1995b).



The NUCSAM Model

Box C; NUCSAM This model is derived from the Regional soil Acidification model (RESAM) coupled to a forest growth model (FORGRO). The model structure is based on the conceptual model of the relation between forest element cycling and acidification. NUCSAM simulates the major hydrological and biogeochemical processes occurring in the forest canopy, litter layer, and mineral soil horizons. The change in soil solution and solid phase chemistry is calculated from a set of conservation equations, describing the input, output, and interactions in each compartment. Vertical heterogeneity is taken into account by differentiating between soil layers. Included hydrological processes are; partitioning of precipitation. into rainfall and snow, interception evaporation from the canopy, transpiration from the soil layers, snowpack accumulation and melt, and a one- dimensional vertical transient water flow in the soil profile. For the hydrological module, an adapted version of the SWATRE model is used. Application of NUCSAM requires data for soil physical and chemical characteristics, rainfall, temperature, global radiation, precipitation and vegetation characteristics.



The MERLIN model.

Box D; ***MERLIN:*** The Model of Ecosystem Retention and Loss of Inorganic Nitrogen (MERLIN) is a process-oriented model for simulating and predicting the timing and nature of nitrogen saturation phenomena. In MERLIN the ecosystem is split into two plant compartments (active and structural biomass) and two soil compartments (labile and refractory organic matter). The carbon pools and fluxes are set external to the model. Nitrogen pools and fluxes are then linked to carbon by C/N ratios in the pools. Transfer between compartments is regulated by central known processes such as plant uptake, litterfall, immobilisation, mineralisation, nitrification, and denitrification. The key to MERLIN is that the rates of these processes is assumed governed by the C/N ratios in the various compartments. MERLIN is thus comprised of (i) a book-keeping procedure in which inputs and outputs of carbon and nitrogen to the ecosystem and between the four compartments are tallied, and (ii) a series of simultaneously acting processes that describe the transfer of C and N between the compartments and out of the ecosystem.

SMART has been used to assess critical loads of acidifying compounds (sulphur and nitrogen) on a European scale, using a database on forest soils compiled during the 1980s (De Vries et al. 1994d) and to evaluate the long-term effects of various emission-deposition scenarios (De Vries et al. 1994b). MAGIC has also been used to assess the critical load of both sulphur and nitrogen for forest soils on a National Scale (Frogner et al. 1995).

Future changes in tree growth due to increased temperature, increased atmospheric CO_2 content and changed nitrogen deposition and soil moisture are an essential part of the nutrient cycle modelling. Modelling the changes in forest growth on a European scale is one of the projects currently funded by the CEC ("ECOCRAFT-The Likely Impact of Rising CO_2 and Temperature on European Forests"). The focus of the modelling effort is directed primarily towards carbon sequestration, forest growth and production. Contacts have already been established with the University of Joensuu (Finland), one of the participating Institutes in ECOCRAFT, to utilise their results here in DYNAMO.

The aim of DYNAMO to assess the consequences of a changed climate, land use and atmospheric composition on forest soils and surface waters in a European scale; special emphasis will be given to the development of techniques for regionalisation. Regionalised models move up in scale from calibrations at individual sites, field plots, stands or catchments, and use spatial information. DYNAMO will not involve the collection of new field data, but will involve the merging and harmonisation of existing data bases (site specific, regional, National, and continental). In a first step the enhanced models will be tested and calibrated on data from intensively monitored sites, with emphasis on sites where large-scale manipulation experiments are, or have been, conducted: RAIN sites in Norway, selected CLIMEX, NITREX, EXMAN sites, integrated monitoring sites under UN/ECE as well as other intensively monitored sites in the participating countries. This part of the project will involve all participating Partners.

2.2 Proposed Work

The main objective of DYNAMO is assess the single and interactive effects of three dominant environmental driving variables on biogeochemical cycling in natural terrestrial and aquatic ecosystems. Acid deposition denotes acidifying compounds derived from emissions of SO_x, NO_x and NH_4 to the atmosphere; global change denotes changes in atmospheric composition, in particular CO_2, and changes in temperature and precipitation as a result of the greenhouse effect; land-use denotes primarily changes in forest management practices, including commercial afforestation (Figure 1). DYNAMO will develop regionalisation approaches to spatially integrate modelled responses and will investigate the ecosystem response to different deposition, land-use, and climate change scenarios. These can be summarised as;

1. *Models*. The models to be used are already developed and previously applied (i.e. accepted off-the-shelf tools). These function at the ecosystem and catchment scale and simulate soil and water chemistry and ecosystems fluxes of major components (Table 1). Some enhancements are needed to include the effects of eg. temperature and CO2 changes on biogeochemical processes (see Workpackage 1), but the changes will be minimal compared to the original model development.

2. *Sites and regions*. For calibration and enhancement of models at different scales, sites with the best, most extensive European data on effects at the stand/catchment level, and at which environmental-driving factors (acid deposition, global change, land-use) have changed either "naturally" or by large-scale manipulation experiment, and at which the ecosystem response has been measured as the change has occurred have been selected (Table 2). Furthermore, these sites are located in areas for which there are extensive regional data such that the site response can be scaled up to the regional/ landscape/ river basin level. These data include regional or national surveys of driving variables (acid deposition, land-use change, climatic variables) and of response variables (stream and lake chemistry, soil, forest growth and vitality). More information on site and regional calibration and scenario analysis is given in Workpackages 2 & 3.

3. *Scenarios*. We will carry out scenarios of future change in environmental driving variables singly and in combination that are realistic for the next 50 years and appropriate for each of the regions and for Europe as a whole (Table 3).

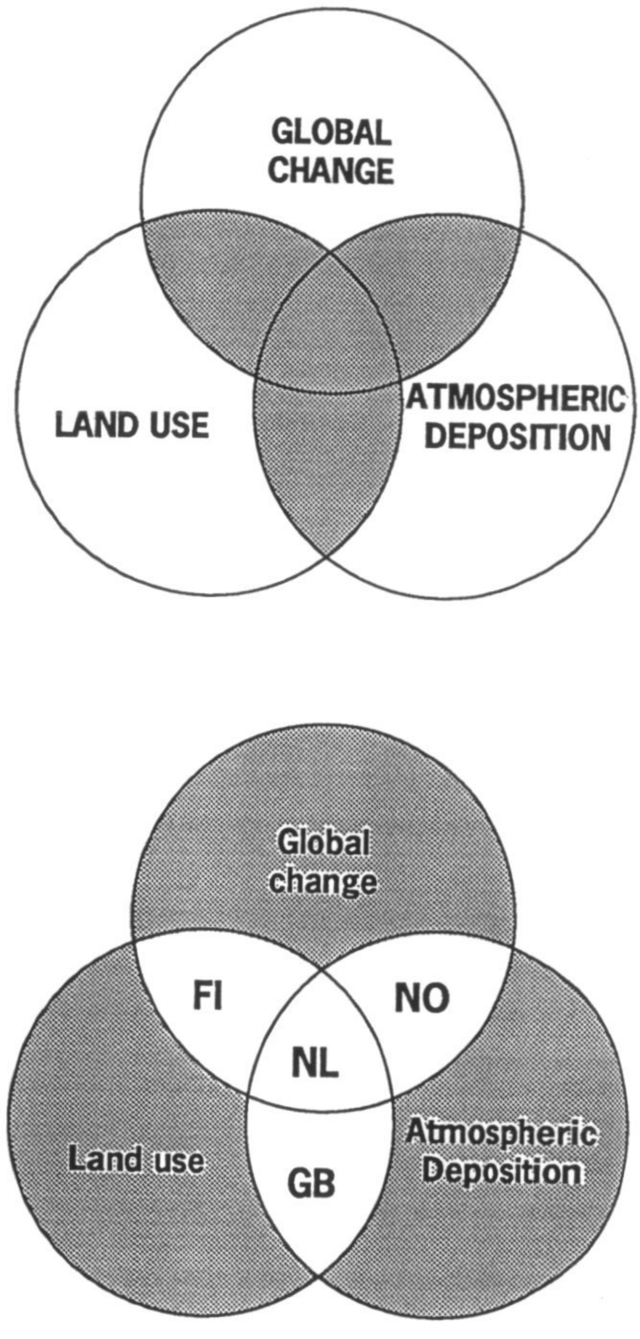


Figure 1. Environmental Driving Variables and Geographic regions at which their impact will be studied by means of dynamic models

Table 1. The dynamic models to be applied at the sites and regions.

	site scale	regional and European scale
Finland	SMART (acidification) TOPMODEL (hydrology) SILMU (nutrients)	SMART2
Norway	MAGIC (acidification) MERLIN (N-cycling)	MAGIC-WAND
Netherlands	NUCSAM (N and C cycling, acidification) MAGIC (acidification) MERLIN (N-cycling)	SMART2 MERLIN
UK	MAGIC (acidification) MAGIC-WAND MERLIN (N-cycling) TOPMODEL (hydrology)	MAGIC-WAND MERLIN

Table 2. The sites and regional data to be used.

	site	experiment/focus	regional data
Finland	Siuntio (SILMU)	forest management	-Kokemänenjoki river basin -national lake surveys 1987, 1995
Norway	Risdalsheia (RAIN, CLIMEX)	roofed catchment with clean rain and climate change (CO_2 and temp.)	-national lake surveys 1974, 1986, 1995 -soil and forest inventories
Netherlands	Speuld (NITREX) Ysselsteyn	roofed stand with clean rain	-national survey of forest stands, 1990, 1995 -UA Veluwe database 1995
UK	Aber (NITREX) AWMN sites (22)	N additions, afforestation, anthropogenic deposition	-survey of forests, Wales -survey of lakes and streams, Wales -survey of lakes in SW Scotland 1979, 1988, 1993, 1994 -Critical load for freshwater sites (>1,200)

Table 3. Examples of scenarios to be used in evaluation of the future impact of environmental change at the site and regional scale. On a European basis, use will be made of the output of GCM and acid deposition models that operate on this scale.

	reduce	**constant (business-as-usual)**	**increase**
acid deposition			
S	80% reduction (1994 Oslo protocol)	constant	-
NO_x	50% reduction	constant	linear at current rate of increase
NH_x	50% reduction	constant	
land-use			
forestry	cut, no replant	cut, replant	new planting, intensive forestry
climate change			
CO_2		constant CO_2	doubling by 2030
temperature		constant	+3-5°C by 2030
precipitation	- 10%	constant	+ 10%

2.3 Work packages

1. Enhancement of the models *Co-ordinator: Jenkins*

Activity 1.1 Model improvement

The model enhancements will be carried out by the Partners which have been instrumental in the initial model development. The inclusion of the nutrient cycle (litterfall, mineralisation and root uptake) and other temperature dependent soil processes (weathering rates, etc.) will be carried out by Partner 03 for the SMART and NUCSAM models, and by Partners 01 and 02 for the MAGIC/ MAGIC-WAND model, whereas Partner 04 will provide and interpret the inputs for the dynamic simulations especially those related to global change, with close collaboration between all Partners concerning the process formulation. Emphasis will be on an aggregated description of the key processes involving nitrogen, carbon and base cation dynamics for long-term regional assessments. The inclusion of the nutrient cycle requires that soils be modelled by including an organic layer. The involvement of the participants of Partners 02 and 05 in ongoing whole-ecosystem manipulation experiments and related modelling exercises funded by the CEC (CLIMEX, NITREX and ENCORE), facilitates the proposed model enhancements.

Activity 1.2 Incorporation of seasonality.

The annual time step used in the present versions of the models does not allow for appropriate simulation of seasonal variations, such as altered precipitation patterns. Therefore, the models will be adapted to a seasonal (monthly) time step and a more refined description of the soil and catchment hydrology. This will be carried out primarily by Partners 02 and 04. The catchment hydrology will be included by linking the soil models with an existing catchment hydrology model (e.g. TOPMODEL, Beven and Kirkby 1979). This will allow the identification of catchment hydrological response such that flow proportioning between soil layers can be derived to enable monthly dynamic changes in soil moisture storage to be ascertained. Seasonality in ecosystem response will be undertaken using data from specific sites in Scotland (Partner 01), following incorporation of a suitable process-based structure for simulating seasonal flow dynamics (Partner 02).

Long-term predictions with the SMART2 model will be compared with those of the validated enhanced NUCSAM to put confidence in the predictions of the regional SMART2 model. Such predictions relate to effects of scenarios for changes in precipitation, temperature and deposition on biogeochemical processes and soil (solution) chemistry, that will be made for the various sites.

Activity 1.3 Standardised forest carbon and nitrogen dynamics

Most (often 90% or more) of the nitrogen in temperate forest ecosystems is found in the soil bound to C in relatively stable organic matter (e.g. Melillo, 1981). These ecosystems may be able to store large amounts of N. The N cycle is connected to the C cycle in the microbial processes of mineralisation and immobilisation. The relative rates of these processes and the competition for N between microbes and plants are hypothesised to determine ecosystem response to increased N deposition (Aber, 1992). Delayed response to increased N deposition (except for hydrological driven nitrate leaching), N turnover, and vegetation in unsaturated (N-limited) systems are probably related to the high C/N ratio of these systems. At high C/N ratios the microbial and plant demand and competition for N is high and probably not relieved in the short term (3 years) even at the high deposition simulated by the addition experiments. The Aber site with an intermediate C/N ratio responded quickly to the increased input of N by increasing N-leaching. Accordingly Data from the 'Integrated Forest Study' in North America suggests that elevated N-leaching occur on sites with soil C/N ratio below 20 and total N-pool greater than 5000 $kgha^{-1}$ (Cole et al., 1992). It is hypothesised that the pool of available C (reflected in the total soil pool of C) is an important parameter regulating the response to increased N deposition and that this relationship can be quantified from empirical data on C and N pools and cycles. Although this approach may highlight the sensitivity of different ecosystems, it does not however elucidate the timing and reversibility of potential saturation responses. Dynamic nitrogen models, such as MERLIN (Text box C), represent the only means by which these responses can be quantified.

Data on C and N pools and cycles as well as other ecosystem characteristics are compiled in the project 'Element Cycling and Output-fluxes in Forest Ecosystems in Europe - ECOFEE' initiated by the Nordic Council of Ministers (Gundersen, 1995). The ECOFEE database is currently being extended to include more sites with all the relevant C and N parameters. The ECOFEE data set will be used to evaluate the role of site specific characteristics (such as forest age, soil C/N ratio, soil type and depth, climatic variables) on rates of processes key to N and C cycles in the various models. Such information is critical in the scaling from MERLIN (site specific, data intensive) to MAGIC-WAND applications and then on to regional applications.

In addition the information from ECOFEE will be used to construct a "standardised" forest ecosystem using composite data from various sites which differ in N loading, growth and site characteristics. These "standardised" forests can then be used in conjunction with site-specific N and C models (MERLIN-type) to evaluate the effect of various deposition scenarios on forests and runoff. This work will be carried out by Per Gundersen, Danish Forest and Landscape Research Institute as a sub-contract to Partner 05 (NIVA).

2. Site applications *Co-ordinator: Wright*

The first step in scaling up in both space and time is the application and evaluation of models at the site scale. Here we have chosen several sites at which there are extensive datasets which give direct information regarding the response of specific environmental driving factors on the biogeochemical cycling and fluxes of water and chemicals to and from the ecosystems. At several of these sites whole-catchment manipulations have been conducted as part of other major projects.

Activity 2.1 Aber, Wales, UK.

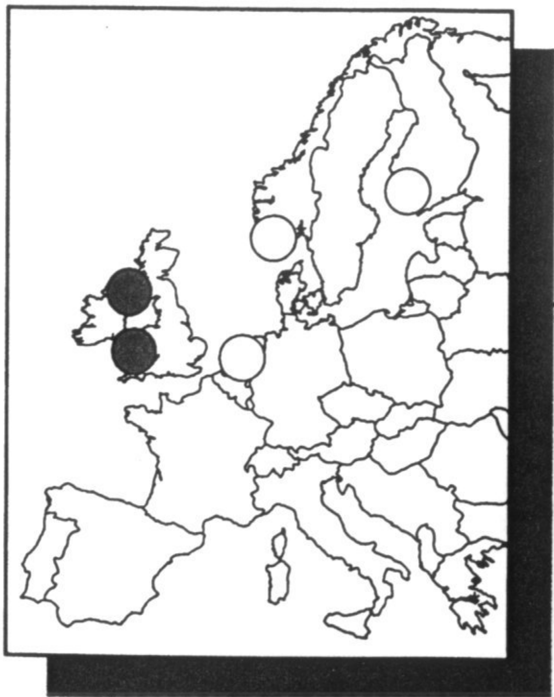
Aber forest, NW Wales, UK, is the site of a series of integrated large-scale ecosystem manipulation experiments with nitrogen deposition carried out as part of the European NITREX project (Emmett et al. 1995). Aber is in mountainous terrain, characterised by 30-year-old Sitka spruce plantation, podzolic soils, and high rainfall. At Aber the interactive effects of forest plantations on former moorlands and acid deposition, in particular nitrogen deposition, are studied. Aber is the locality at which MERLIN, Model of Ecosystem Retention and Loss of Inorganic Nitrogen, was developed (Cosby et al. 1995b (in prep.). At Aber the MAGIC (Cosby et al. 1985a) and MERLIN models will be calibrated and used to predict the effects of scenarios of land-use (in particular forest management) and acid deposition on the fluxes of water and pollutants from the ecosystem.

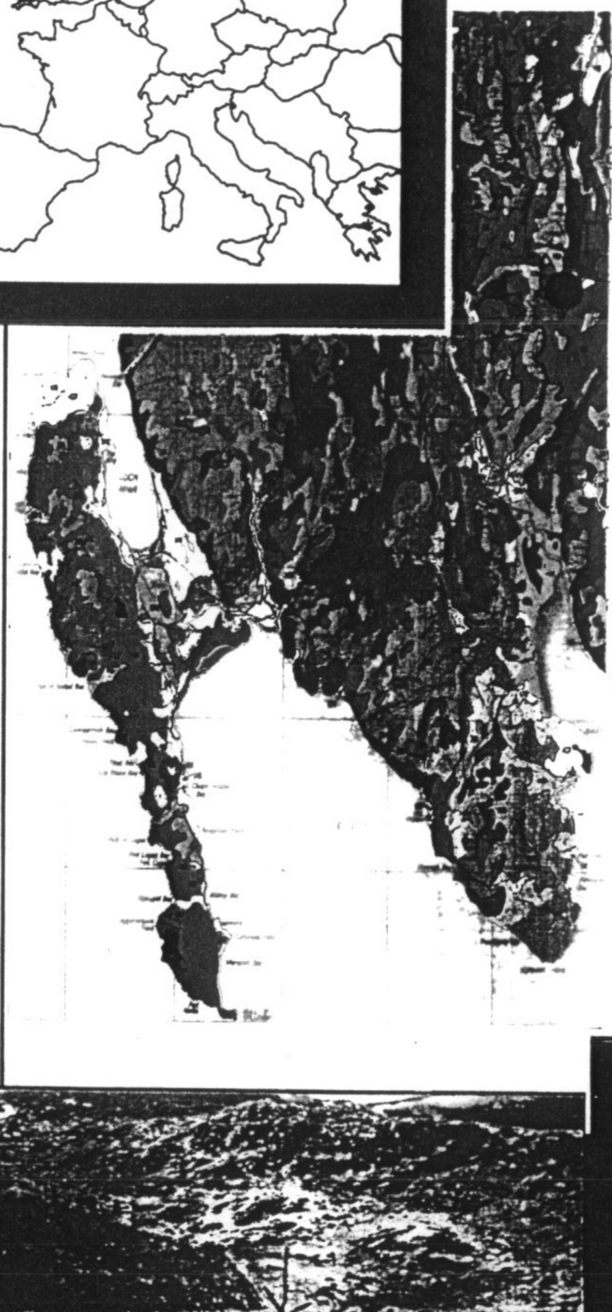
Activity 2.2 Siuntio and Nurmes, Finland.

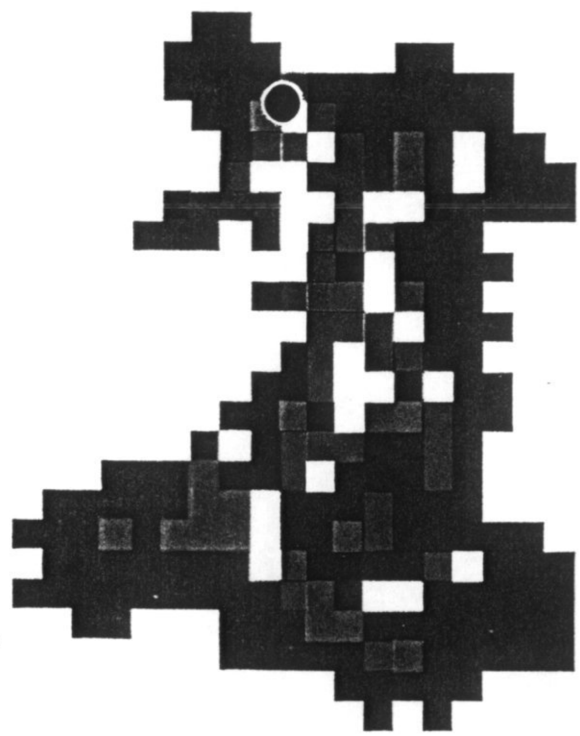
The Rudbäck catchment, a forested catchment located in Siuntio, southern Finland (60 08 N, 24 18 E), with spruce and pine as main tree species, has been sampled for various forest and soil characteristics, and monitored intensively for water quality during the Finnish Research Programme on Climate Change (SILMU). The objective of applications to Rudbäck is to analyse the potential implications of documented climate change scenarios on leaching of materials from forest soils.

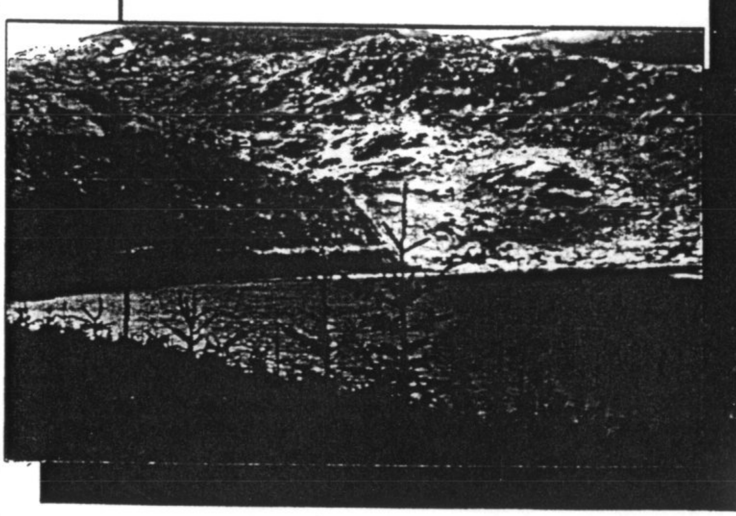
The Nurmes experimental area consists of six catchments, situated in two clusters; two catchments located in Valtimo (63 45 N, 28 30 E), and four adjacent catchments in Sotkamo (63 52 N, 28 30 E). The catchments are growing mainly coniferous forests on peat or moraine soils. Four catchments have been treated with different silvicultural measures: clear-cutting, ploughing, draining and/or mounding, followed by replanting (Ahtiainen 1992). Two catchments are kept as reference basins with no management measures applied. Continuous flow measurements, frequent water quality data, as well as necessary soil and forest data are available for the experimental basins. The objective of the applications to Nurmes catchments is to analyse the relative importance of climate change in comparison with effects of land use on leaching of materials to surface waters. At these sites applications will use the SMART model. Catchment hydrology will be included by linking the soil model with an existing catchment hydrology model (HBV/TOPMODEL).

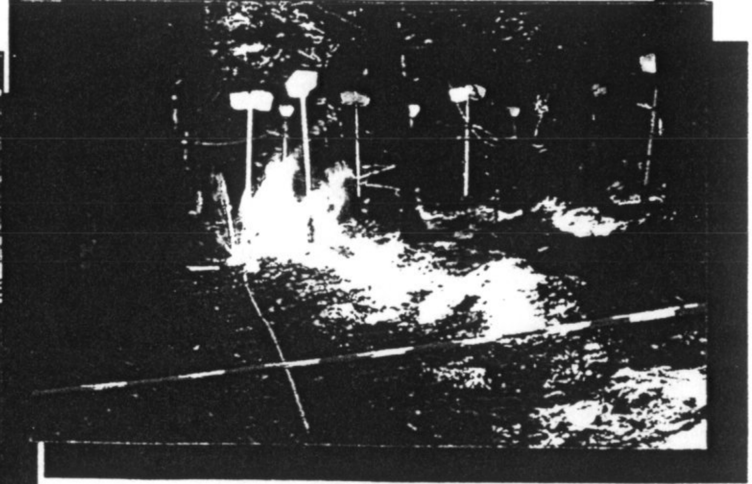
UNITED KINGDOM











Activity 2.3 Risdalsheia, Norway.

Risdalsheia is the site of the whole-catchment manipulation experiments with acid rain (RAIN project, Wright et al. 1993) and more-recently with climate change (CLIMEX project, Jenkins et al.1993). Here two whole catchments are covered by roofs under which the deposition quality and climate parameters are manipulated. Investigations under way in CLIMEX include studies of vegetation response, soils dynamics and hydrochemical changes.

Several models will be calibrated and evaluated using the data from Risdalshiea. The acidification model MAGIC has previously been applied (Wright et al. 1990). We will apply MERLIN, and then couple MAGIC with MERLIN to evaluate the effect of altered deposition quality on cycling of nutrients and acidification of soils and waters. As the data from CLIMEX become available, temperature and CO_2 dependence will be added to the various processes included in these models. The objective is to obtain a calibrated model or set of models describing the combined effects of acid deposition and global change on soil and surface water chemistry. Of particular interest will be the release, mobility and fate of dissolved nitrogen, carbon, and phosphorus compounds as well as acidification parameters.

Activity 2.4 Speuld and Ysselsteyn, the Netherlands.

Speuld is the site of a 30-year-old Douglas fir plantation, at which large-scale manipulations have been carried out as part of the NITREX project (Boxman et al. 1995). The site is located in central Netherlands on well-drained, acidic sandy soils and receives extremely high deposition of acidic compounds, in particular nitrogen pollution. The response of the ecosystem to reduced deposition of pollutants has been studied by a large-scale experimental programme in which a roof beneath the tree canopy acts to exclude acid throughfall. Clean rain is added beneath the roof. Ysselsteyn is forested with 45 year old Scots pine and receives a nitrogen load of nearly 60 $kgha^{-1}$. At Speuld and Ysselsteyn, several models will be calibrated (MERLIN, SMART2 and NUCSAM) and their compatibility and applicability assessed.

Activity 2.5 Acid Waters Monitoring Network, UK

The MAGIC-WAND model will be calibrated to the twenty two sites of the UK Acid Waters Monitoring Network covering spatial gradients of anthropogenic deposition, rainfall, and seasalts, to determine major sensitivities (Partner 02 IH). These sites cover a large range of different ecotypes with different geology, soils, and age and extent of afforestation, and monitoring has been carried out over the last five years. At specific AWMN sites (initially in SW Scotland) seasonal responses will be calibrated in conjunction with model improvements on describing soil and catchment hydrology on a monthly basis (Partner 01 MLURI).

3. Regional applications: *Co-ordinator: de Vries*

This work package follows on from the site specific applications undertaken in work package 1, however the assimilation and collation of appropriate datasets for the regional applications will run concurrently with the detailed applications. The aim of the regional modelling is two fold; (1) the scaling up of responses determined and modelled at the catchment and site specific to the larger geographical units of landscape, river basin, region, and continent, and, (2) to determine relative merits of the different regional modelling approaches.

Activity 3.1 Regional application to Wales.

The first specific activity is to apply the MAGIC-WAND model to Wales using regional databases on soils and water quality (Partner 02 IH). The regional methodology will be a two-stage coupling of monte-carlo simulations with a calibration procedure designed to produce a fit to the joint distribution of key freshwater quality variables. Application of MAGIC-WAND to the Acid Waters Monitoring Network sites will be carried out to determine processes such as catchment uptake, mineralisation, immobilisation on a regional basis. A monte-carlo simulation will then be undertaken following calibration of MAGIC-WAND to data from >120 forested sites. Analysis will be undertaken to determine the sensitivity of model parameterisation to regionally defined characteristics, and will compare modelled and observed regional hydrochemistry. Following the site specific application of the MERLIN model at Aber, a further monte-carlo analysis will be undertaken using regional characteristics and detailed data from the Welsh regional forest survey. This will investigate the sensitivity and applicability of the MERLIN model in a regional framework.

Activity 3.2 Landscape scale regionalisation, Scotland.

Following the use of the MERLIN model to identify generic responses of forest growth dynamics during rotation of commercial forest crops, a MAGIC-WAND regional application will be conducted using data from forty lochs and their catchments in SW Scotland. The development and application of a multiple calibration regional approach will be the responsibility of Partner 01 MLURI. Data collected include regional surveys of water quality over the period 1978 to 1994, detailed history of land use changes, and soils data from the UK National Soils Inventory. Forest data will be incorporated which will represent the age and extent of afforestation in each individual catchment and including any historical changes.

Activity 3.3 Extrapolation to river basin scale, Finland.

Partner 04 will undertake regional model applications in Finland which will be focused on one river basin, River Kokemäenjoki in western Finland. The total area of the river basin is 27 000 km^2 of which 3 000 km^2 is lake area. The mean discharge of the watercourse is $210 m^3 s^{-1}$. Two types of regional applications will be performed for the River Kokemäenjoki area making use of both conceptual and stochastic regionalization techniques. The conceptual regional model to be developed consists of two components: a runoff model and a nutrient transport model (Bilaletdin et al. 1994)

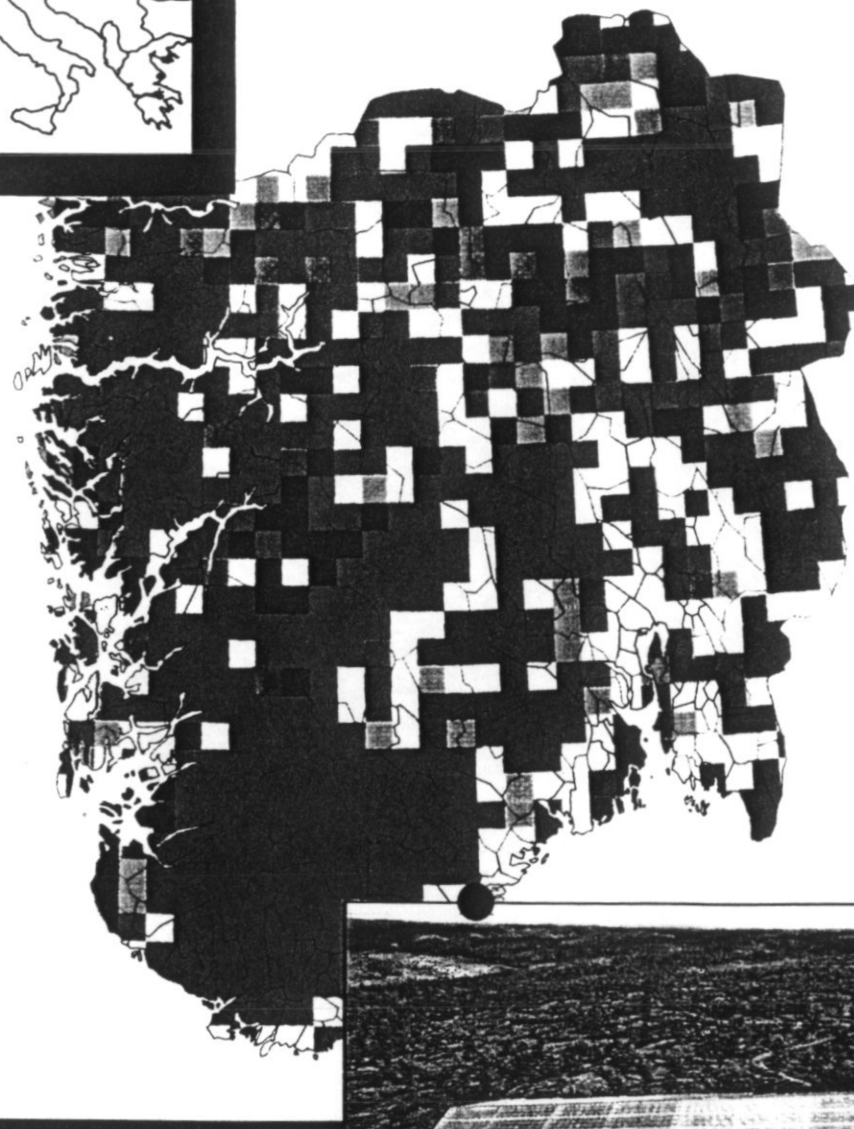
The runoff model is a modification of the HBV-model, a relatively simple conceptual runoff model, producing runoff, soil frost and soil moisture as output. The nutrient transport model has been developed as part of SILMU. The model has a number of independent parameters, part of them being calibrated, part of them describing characteristics of the sub-basins and climate. Total phosphorus and nitrogen transports are calculated separately for forested and agricultural areas by calculating nutrient concentrations as a function runoff, catchment area, lake percentage, soil frost, soil moisture, mean slope, soil type, land cover type, forestry and agricultural practices. The functions are obtained from empirical data and from site specific model applications. The overall nutrient transport for the entire river basin can be obtained by summing over the various sub-basins.

The stochastic regionalisation techniques in which inputs for model runs are selected from input and parameter distributions for specified regions (e.g. Posch and Kämäri 1990) are further developed for (random) survey data. The data base to be used is obtained from the nation-wide statistically based lake survey, to be conducted in fall 1995 in all three countries, Finland, Norway, and Sweden, using similar principles. The lakes from the Kokemäenjoki river basin form the target water quality distribution of the stochastic calibration. Available soil survey data form the target soil status distribution. The input information for the SMART model is obtained from available soil and GIS information by which all relevant vegetation, soil and rock type information is mapped for all lake catchments. Since many of the model variables and driving forces are only poorly known, especially on a regional scale, sensitivity and uncertainty analysis will be an important part of the proposed model applications. The calibrated regional models can provide information on the magnitude of material leaching from the forested catchment areas to lakes under assumed climate change, land use and deposition scenarios.

Activity 3.4 Regionalisation to the landscape scale. Southernmost Norway.

Partner 05 NIVA will utilise the data and site-specific model applications at the RAIN/CLIMEX experiment site at Risdalsheia to scale-up to the upland, sparse forest landscape typical of southernmost Norway. The regional data to be used include (1) national surveys of forest soils and forest status collected over a 9 x 9 km grid, (2) national surveys of lake water chemistry collected in 1974, 1986 and 1995 and (3) meteorological and precipitation quality data. A similar technique used in activity 2.1 (Regional application to Wales) will be used by which Monte-Carlo simulations will generate statistical distributions calibrated to fit the joint distributions of key variables. The regionalised model will then be run under several scenarios of future climate change and acid deposition. This approach has previously been used to evaluate future scenarios of acid deposition on lake water acidification in southernmost Norway (Wright et al 1991)

NORWAY



Activity 3.5 Regionalisation to National scale, UK

Partners 01 MLURI & 02 IH will undertake a multiple calibration of MAGIC to 1,200 sites, which forms the core of the critical loads and acid deposition for the UK freshwater database which represent samples taken from a 10 x 10 km grid in regions of high or medium acid sensitivity, and a grid of 20 x 20 km in areas considered to be of low sensitivity to anthropogenic deposition. Highest resolution soils data from the National Soils Inventory will be utilised, and future responses to different scenarios determined in a spatial framework linked to a GIS.

Activity 3.6 Regionalisation to a National scale, the Netherlands

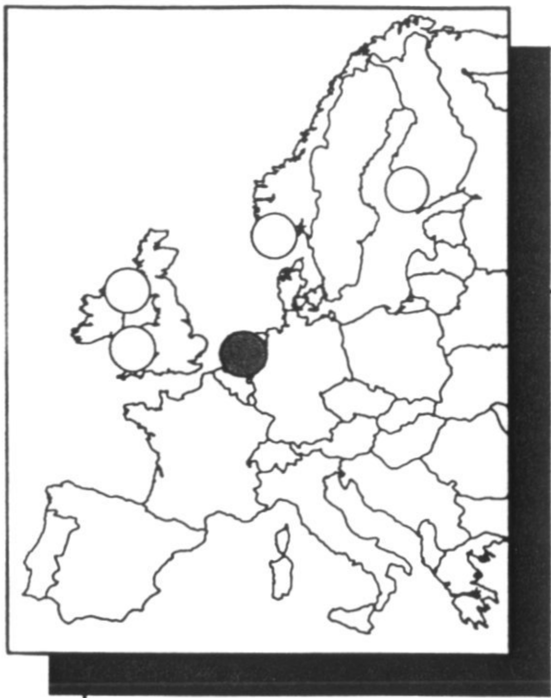
MERLIN will be applied to 20 forested sites in the Veluwe, where a substantial database exists on tree species, age, base saturation of the soils, nitrogen deposition, as well as carbon pools and nitrate leaching. This will be undertaken by A. Tietema of the University of Amsterdam as part of a sub-contract to Partner 05.

The SMART model will be used for scenario analysis at a National scale in the Netherlands (Partner 03 SC-DLO). Modelled output will be compared with large scale survey data on the soil solution chemistry below forests, and on the pH and base saturation data of forest soils in the Netherlands.

Activity 3.7 Continental scaling.

SMART2 will be scaled up to a European scale by using (existing and forthcoming) data bases and transfer functions as well as appropriate interpolation techniques (De Vries et al.1994). The analyses will be performed by comparing frequency distributions of model results and data while differentiating between tree species and soil types (National scale) or between regions with similar deposition levels, soil types etc. (European scale). Since several of the model variables are either poorly known or highly variable on a regional scale, the data bases will include the distribution (ranges of uncertainty and/or variability) of each variable needed for simulation. Uncertainty ranges in model results, induced by uncertainties in model inputs, will be given by using monte carlo simulation techniques (Kros et al.,1993). To reduce the uncertainty in model results, highly sensitive and uncertain model parameters, will be calibrated by minimising the difference between data and model results, using multi-signal calibration techniques (Kros et al. 1994). Insight in such parameters will be ascertained by sensitivity and/or uncertainty analyses. Such a regional model calibration is of utmost importance and ensures confidence in SMART results for future scenarios of global change that will be assessed for the considered region. This will also be liked to modelling initiatives using MAGIC-WAND (Partner 05 NIVA) and the ECOFEE database.

Scenarios for the European application will be based on results from the global circulation model IMAGE (temperature and precipitation) and the emissions-deposition model RAINS (atmospheric deposition of SO_X, NO_X, and NH_X).



NETHERLANDS

The link between the various models will be established by adapting the temporal and spatial scale of the outputs of IMAGE and RAINS to the input requirements of SMART2. The inter-relation of climate change and atmospheric deposition will thus be assessed for different relevant policy scenarios.

4. European conference: *Co-ordinator: Ferrier*

At the end of the second year of the work programme we intend to hold an International meeting on dynamic modelling at a suitable European venue. This conference will be promoted by means of circulars, and active participation from overseas modelling groups will be encouraged. During a Conference on Ecosystem Manipulation (Bowness on Windermere, October 1994) the development and application of dynamic models was considered to be of high priority, especially models which would complement the detailed process oriented studies being undertaken at different manipulation experiments. The proposed conference will focus primarily on the potential for scaling up the responses modelled at specific sites to the regional and continental scales. Such an objective, which is the basis of DYNAMO, is complementary with both the International ecosystem manipulation initiatives, and forms an interface with the requirements of resource managers and policy makers for scenario determination at different spatial scales.

2.4 Relationship to Workprogramme

DYNAMO is designed specifically to address the objectives of Terrestrial Ecosystems Research Initiative (TERI) Science plan theme 5: Integration, up scaling and scenario studies. DYNAMO focuses on moving from short-term site-specific ecosystem experiments (conducted as part of other EU projects) to long-term landscape and regional predicts of the impacts of global change, acid deposition and land-use on terrestrial ecosystems and the resultant effects on aquatic ecosystems. DYNAMO will place the site-specific results into an European context.

Three of the sites used in DYNAMO are sites of high activity with multiple and linked ecosystems studies and experiments. These sites thus also fall under the TERI concept. Complete, ongoing and proposed projects at Aber, Wales, UK (Table 4a), the Veluwe, NL (Table 4b), and Risdalsheia (Table 4c) include transect projects such as NITREX (Aber, Wales and Speuld (located in the Veluwe)), investigations of several types of ecosystem such as grassland and forest at one site (Aber), and experimental manipulations with several environmental driving variables (Risdalsheia). The connection between detailed process-studies at individual sites up to European-scale scenario models is especially strong in DYNAMO due to the direct co-operation and involvement of scientists active at all levels.

Ecosystem	Project name	Status	TERI themes	References
Coniferous Forest	NITREX	on-going	3.1; 3.2	1
	ENCORE (harvesting)	completed	1; 3.2	2
	Stand development	completed	3.2	3
	DYNAMO	proposed	1; 2; 3; 5.	4
Wetland	Effects of drought	on-going	2; 3.2	5
	PEGASAS	proposed	3.2	6
Deciduous woodland	FESTIVE	proposed	2; 3.1; 3.2; 5	7

Table 4a; Aber, Wales.

Ecosystem	Project name	Status	TERI themes	References
Coniferous	NITREX	on-going	2; 3.1; 3.2	8
Forest	EXMAN	on-going	2; 3.1; 3.2	9
	ACIFORM	completed	2; 3.1; 3.2	10
	CORE	on-going	2	11
	Humus forms	completed	3.1; 3.2	12
	DYNAMO	proposed	1; 2; 3; 5	4
Deciduous	N cycling	completed	2; 3.2	13
Heathland	N deposition	completed	2; 3.1; 3.2	14
	Species competition	completed	2; 4	15

Table 4b; the Veluwe, Netherlands

Ecosystem	Project name	Status	TERI themes	References
	ENCORE	completed	3.2	16
	RAIN	completed	3.2	17
Coniferous	CLIMEX	on-going	2; 3.1; 3.2; 5	18
Forest	FESTIVE	proposed	2; 3.1; 3.2; 5	7
	PROTOS	proposed	2; 3.1	19
	DYNAMO	proposed	1; 2; 3; 5.	4

Table 4c; Risdalsheia, South-western Norway

1) Emmett *et al* 1995. Nitrogen additions ($NaNO_3$ and NH_4NO_3) at Aber forest, Wales: I. Response of throughfall and soil water chemistry, and II. Responses of trees and nitrogen transformations. For. Ecol. Manag. 71, 45-59 & 61-73.
2) Reynolds *et al.* (1992) Effects of clearfelling on stream and soil aluminium chemistry in three UK forests. Environ. Pollut. 77, 157-165.
3) Emmett,B.A. *et al.*(1993) Nitrate leaching from afforested Welsh catchments- interaction between stand age and nitrogen deposition. Ambio, 22, 386-394.
4) Ferrier,R.C. *et al.* This proposal.
5) Freeman,C. *et al.*(1994) Fluxes of CO_2 and N_2O from a Welsh peatland following simulation of water table drawdown: potential feedback to climatic change. Biogeochemistry, 19, 51-60.
6) Dise *et al.* (1995) PEGASAS- Peatlands, acid deposition and greenhouse gas study. A research proposal. The Open University.
7) Tietema, A. *et al.* (1995) FESTIVE - Forest Ecosystems and Temperature Investigations. A research proposal. The University of Amsterdam.
8) Wright,R.F. and van Breemen,N. 1995 The NITREX Project: an introduction. Forest Ecol. and Manag. 71, 1-5.
9) Beier,C. and Rasmussen,L. 1993 The EXMAN Project. Experimental manipulation of forest ecosystems in Europe. Ecosystems Research Report 7, 124pp.
10) Heij,G.J., and Schneider,T 1991 Acidification research in the Netherlands. Final report of the Dutch Priority Programme on Acidification. Studies in Environmental Science, 46, 771pp.
11) Anderson,J.M. *et al* 1995 Effects of air pollutant-temperature interactions on mineral-N dynamics in replicate forest soil transplantation. Commission of European Communities International symposium on Ecosystem Manipulation, Windermere Oct. 1994.
12) Emmer,I.M. 1995 Humus form characteristics in relation to undergrowth vegetation in a *Pinus sylvestris* forest. Acta Oecologia (in press).
13) Tietema,A. *et al* 1993 Nitrogen transformations in four acid soils subject to increased nitrogen deposition. Forest Ecol. and Manag. 57, 29-44.
14) van der Eerden,L.J. *et al.* Influence of NH_4 and $(NH_4)_2SO_4$ on heathland vegetation. Acta Botanica Neerlandica 40, 281-296.
15) Berendse,F.R. *et al* 1989 A comparative study on nutrient cycling in wet heathland ecosystems. II Litter decomposition and nutrient mineralization. Oecologia, 78, 338-348.
16) Jenkins,A. Wright,R.F., and Cosby,B.J. 1994 Modelling the long-term hydrochemical response at ENCORE catchments in the UK and Norway. Acid Rain Research Report No. 35, NIVA, Oslo.
17) Wright,R.F., Lotse,E., and Semb,A. (1993) RAIN Project: results after 8 years of experimentally reduced acid deposition to a whole catchment. Can. J. Fish. Aquat. Sci., 50, 258-268.
18) Jenkins,A. and Wright,R.F. (1994) The CLIMEX project - raising CO_2 and temperature to whole catchment ecosystems p. 211-219 In: Methodologies to assess CO_2 effects on terrestrial ecosystems. Ecosystems Research Report 5, Commission of European Communities, Brussels.
19) Mulder,J. et al. (1995) PROTOS - Production and transport of organic solutes in forest ecosystems: effects of natural climatic variation (a proposal) Norwegian Forest Research Institute.

2.5 References.

Aber,J.D. 1992. Nitrogen cycling and nitrogen saturation in temperate forest ecosystems. Trends. Ecol. Evol., 7, 220-223.

Aber,J.D., Driscoll,C., Federer,C.A., Lathrop,R., Lovett,G., Melillo,J.M., Steudler,P. and Vogelmann,J. 1993 a strategy for the regional analysis of the effects of physical and chemical climate change on biogeochemical cycles in north-eastern US forests. Ecological Modelling, 67, 37-47.

Ahtiainen, M 1992. The effects of clear cutting and scarification on the water quality of small brooks. Hydrobiologia, 243/244, 465-473.

Beven,K.J. and Kirkby,M.J. 1979 a physically based, variable contributing area model of basin hydrology. Hydrological Sciences, 24, 43-69.

Boxman, A.,W., Dam, D. van, Dijk, H.F.G. van, Hogervorst, R.F., Koopmans,C.J. 1995. Ecosystem responses to reduced nitrogen and sulphur inputs into two coniferous stands in the Netherlands. Forest Ecol and Manag. 71, 7-29.

Cole,D.W. 1992. Nitrogen chemistry, deposition and cycling in forests. In: Integrated Forest Study Programme. Springer Verlag, New York.

Cosby,B.J., Hornberger,G.M., Galloway,J.N. and Wright,R.F. 1985a. Modelling the effects of acid deposition: assessment of a lumped parameter model of soil and streamwater chemistry. Water Resources Research, 21, 51-63.

Cosby,B.J., Wright,R.F., Hornberger,G.M., and Galloway J.N. 1985b. Modelling the effects of acid deposition: estimation of long term water quality responses in a small forested catchment. Water Resources Res. 21, 1591-1601.

Cosby,B.J., Ferrier,R.C., Jenkins,A., Emmett,A.B., Tietema,A and Wright,R.F. 1995a. Modelling the effects of nitrogen deposition at the catchment scale: A Model of Ecosystem Loss and Retention of Inorganic Nitrogen (MERLIN). in prep.

Cosby,B.J., Emmett,B.A., Tietema,A., Wright,R.F., Ferrier,R.C. and Jenkins,A. 1995b Modelling the effects of nitrogen deposition at the catchment scale: Simulation of nitrogen saturation in an afforested system at Aber, Wales. in prep.

Emmett,B.A., Brittain,A., Hughes,S, and Kennedy,V. 1995. Nitrogen additions ($NaNO_3$ and NH_4NO_3) at Aber forest, Wales . II. Responses of trees and soil nitrogen transformations. For Ecol. and Manag. 71, 61-73.

Ferrier,R.C., Vries, W. de, and Warfvinge,P 1995a The use of dynamic models for the determination of critical loads for nitrogen: Developments since Lökeberg. UNECE Workshop on N deposition and its effects: critical loads and mapping. Grange over Sands, Nov. 1994. in press.

Ferrier,R.C., Wright,R.F., Cosby,B.J., and Jenkins, A. 1995b Application of the MAGIC model to the spruce stand at Solling, Germany. Ecological Modelling. in press.

Forsius,M., Kämäri,J. and Posch,M. 1992. Critical loads for Finnish lakes: comparison of three steady-state models. Environmental Pollution 77, 177-193

Frogner, T., Wright,R.F., Cosby,B.J. and Esser,J. 1994 Maps of critical load exceedance for sulphur and nitrogen to forest soils in Norway. NIVA Report No. 0-91147, Oslo, Norway.

Groenenberg, J.E., Kros, J., van der Salm,C., and Vries, W. de 1995. Application of the NUCSAM model to the Solling spruce site. Ecological modelling (in press).

Gundersen,P. and Rasmussen,L. 1995. Nitrogen mobility in a nitrogen limited forest at Klosterhede, Denmark, examined by NH_4NO_3 addition. Forest Ecol and Manag., 71, 75-88.

Hettelingh, J-P, Gardiner,R.H., and Hordijk,L. 1992. a statistical approach to the regional use of critical loads. Environmental Pollution 77, 177-183.

Jenkins, A., Whitehead,P.G., Musgrove,T.J., and Cosby,B.J. 1990 A regional model of acidification in Wales. Journal of Hydrology, 116, 403-416.

Jenkins, A., R.F. Wright, F. Berendse, N. Van Breemen, L. Brussaard, E.D. Schulze, and F.I. Woodward. 1993. The "CLIMEX" project - Climate Change Experiment. p. 71-77, In: Rasmussen, L., T. Brydges, and P. Mathy, (eds.). Experimental Manipulations of Biota and Biogeochemical Cycling in Ecosystems. Ecosystem Research Report 4, Commission of the European Communities, Brussels, 348pp.

Kämäri, J., Brakke,D.F., Jenkins,A., Norton,S.A., and Wright,R.F. 1989. Regional Acidification Models- Geographic extent and time development. Springer Verlag.

Kämäri, J., Forsius,M., and Posch,M. 1993 Critical loads of sulphur and nitrogen for lakes II Regional extent and variability in Finland. Water, Air, and soil Poll., 66, 77-96.

Kros,J. Heuberger,P.S.C., Janssen,P.H.M. and Vries, W. de 1994 Regional calibration of a steady state model to assess critical acid loads. In: Proceedings of a symposium on predictability and non-linear modelling in natural sciences and economics. Wageningen Agricultural University, April 5-7, 1993.

Kros, J., Groenenberg, J.E, Vries, W de, & van der Salm,C. 1994. Uncertainty due to time resolution in long term predictions of forest soil acidification. Water, Air and Soil Poll. (in press).

Posch, M., and Kämäri,J. 1990 Modelling regional acidification of Finnish Lakes In: J.Kämäri (Ed.) Impact models to assess regional acidification. Kluwer Academic Publishers, pp 145-166.

Posch,M., Reinds,G.J., and de Vries, W. 1993. SMART - A simulation model for acidification's regional trends: model description and user manual. Mimeography Series of the National Board of Waters and the Environment, 477, Helsinki, Finland, 43pp.

Salm,C. van der, Kros,J. Groenenberg,J.E., Vries, W.de, & Reinds, G.J. 1994 Validation of soil acidification models with different degrees of process aggregation on an intensively monitored spruce site, In Trudgill, S. (Ed.) Solute modelling in catchment systems.

Wright, R.F., B.J. Cosby, R.C. Ferrier, A. Jenkins, A.J. Bulger, and R. Harriman. 1994. Changes in the acidification of lochs in Galloway, south-western Scotland, 1979-1988: the MAGIC model used to evaluate the role of afforestation, calculate critical loads, and predict fish status. J. Hydrol. 161: 257-285.

Wright, R.F., B.J. Cosby, M.B. Flaten, and J.O. Reuss. 1990. Evaluation of an acidification model with data from manipulated catchments in Norway. Nature 343:53-55.

Wright, R.F., B.J.Cosby, and G.M. Hornberger. 1991. A regional model of lake acidification in Southernmost Norway. Ambio 20, 6, 222-225.)

Wright, R.F., E. Lotse, and A. Semb. 1993. RAIN project: results after 8 years of experimentally reduced acid deposition to a whole catchment. Can. J. Fish. Aquat. Sci. 50: 258-268.

Vries W. de, Posch,M. and Kämäri, J 1989. Simulation of the long term soil response to acid deposition in various buffer ranges. Water, Air and Soil Poll. 48, 349-390.

Vries, W. de , Posch, M., Reinds, G.J., and Kämäri,J. 1992. Critical loads and their exceedance on forest soils in Europe. The Winand Staring Centre for Integrated Land, Soil, and Water Research, Report 58, Wageningen, The Netherlands, 126pp.

Vries, W. de, Reinds, G.J., Posch,M., and Kämäri,J. 1993. Long term soil response to acidic deposition in Europe. Water, Air and Soil Poll.

Vries, W. de, Kros, J. & van der Salm, C. 1994a The long term impact of three emission-deposition scenarios on Dutch forest soils. Water, Air and Soil Poll., 75, 1-35.

Vries, W. de, Reinds, G.J., Posch,M., and Kämäri,J. 1994b Long term soil response to acidic deposition in Europe. Water, Air and Soil Poll. 78, 215-246.

Vries, W de, Kros, J., Voogd, J.C.H. 1994c. Assessment of critical loads and their exceedance on Dutch forests using a multi-layer steady state model. Water, Air and Soil Poll., 76, 407-448.

Wries, W. de, Reinds, G.J., and Posch, M. 1994d. Assessment of critical loads and their exceedance on European forests using a one-layer steady-state model. Water, Air and Soil Poll., 72, 357-394.

3. Milestones and deliverables

Evaluation of the project output measured against all work activities and work packages will be assessed at annual project meetings to be held in October (for the previous years review). Project reports will include the main scientific advances of DYNAMO, and summaries of individual site and regional modelling applications.

The deliverables from DYNAMO will be primarily in the form of reports and publications of the scientific information resulting from the project. All will be in the public domain, with restriction of access (see Table 7 for timing of reports).

Schedule

Year 1.

- Start with site calibrations and applications.
- Collection of regional and European data.
- Specification of scenarios at site and regional scales
- Plan European conference

Year 2.

- Scenarios at multiple-sites
- Model comparison at selected sites.
- Regional calibrations and applications.
- Initiate European calibrations.
- Hold European conference on use of dynamic models for regional prediction of impacts

Year 3.

- Model comparison at Ridsalsheia, for the assessment of global change.
- Regional scenarios, and comparison of modelling approaches for regionalisation.
- Continental scenarios.

4. Benefits

DYNAMO is of European scale and global relevance. Results from DYNAMO contribute to a scientific base upon which emissions policies for major air pollutants gases (acid precursors SO_x, NO_x, NH_4: greenhouse gases CO_2) and land-use management policies are decided.

DYNAMO specifically fulfils objectives in TERI's thematic area 5 (Integration, up scaling and scenario studies) and thus represents a major EU contribution to the IGBP (International Geosphere-Biosphere Programme).

DYNAMO is clearly a European level project. The terrestrial ecosystems to be studied by DYNAMO and the terrestrial-aquatic linkages are found in many northern European countries, and indeed at high latitudes over much of the northern hemisphere. The results are thus of pan-European significance.

Since this project deals with the development of methods for assessing ecological impacts, there are no direct economic or technical benefits to be expected. However, the techniques and models to be developed are of clear relevance for, (i) decision making process in the formation of European Environmental policy, (ii) policies related to the UN/ECE Convention on Long Range Transboundary Air Pollution (LRTAP) and related protocols on the reduction of acidifying substances, and (iii) international policy developments on the emissions of greenhouse gasses.

5. Economic and social impacts

Not applicable.

6. Project management structure.

01 MLURI *Ferrier*. Co-ordinator. Forest and land-use management and interactions acidification in Scotland and UK, and landscape scale modelling.

02 IH *Jenkins, Emmett*. Land-use change and acidification at Aber, regionalisation to Wales and UK. Model development for seasonality and spatial integration.

03 SC-DLO *deVries*. Acidification and temp/soil moisture at Speuld, regionalise to Netherlands. Model comparison (acidification models MAGIC, SMART; N cycling models MERLIN, NUCSAM) at Speuld. Sub-contracts to Jan Roelofs, Catholic University of Nijmegen (KUN), and Douwe van Dam, Agricultural University of Wageningen (LUW).

04 FEA *Kämäri*. Forest management and climate change in Finland. River basin and National scale regionalisation. Sub-contract to Tom Frisk at HAME Regional Environment Centre,Tampere.

05 NIVA *Wright*. Acid deposition and climate change at Risdalsheia (CLIMEX), regionalise to S. Norway. Model comparison at Risdalsheia (acidification models MAGIC, SMART; nitrogen/climate change models MERLIN, NUCSAM). Sub-contract to Albert Tietema UA to run MERLIN and MAGIC at Speuld, and to use MERLIN for regionalisation in the Veluwe. Sub-contract to Per Gundersen, Danish Forest and Landscape Research Institute for techniques of regionalisation using the ECOFEE database. Link to IGBP-GCTE and LEMA (Jack Cosby).

The structure of the partnership, indicating all sub-contractors and affiliated sister Institutes is presented in Table 5. The involvement of the various Partners in individual activities within the work packages is highlighted in Table 6, and this includes Partners that have a secondary involvement. The activity "techniques for model regionalisation" will be collaborative venture involving all Partners, and this will form a major component of the project. Table 7 shows the approximate timing and duration of the various activities and work packages. It is intended to hold at least two full Partnership meetings per year, and annual progress reports of DYNAMO will also be produced.

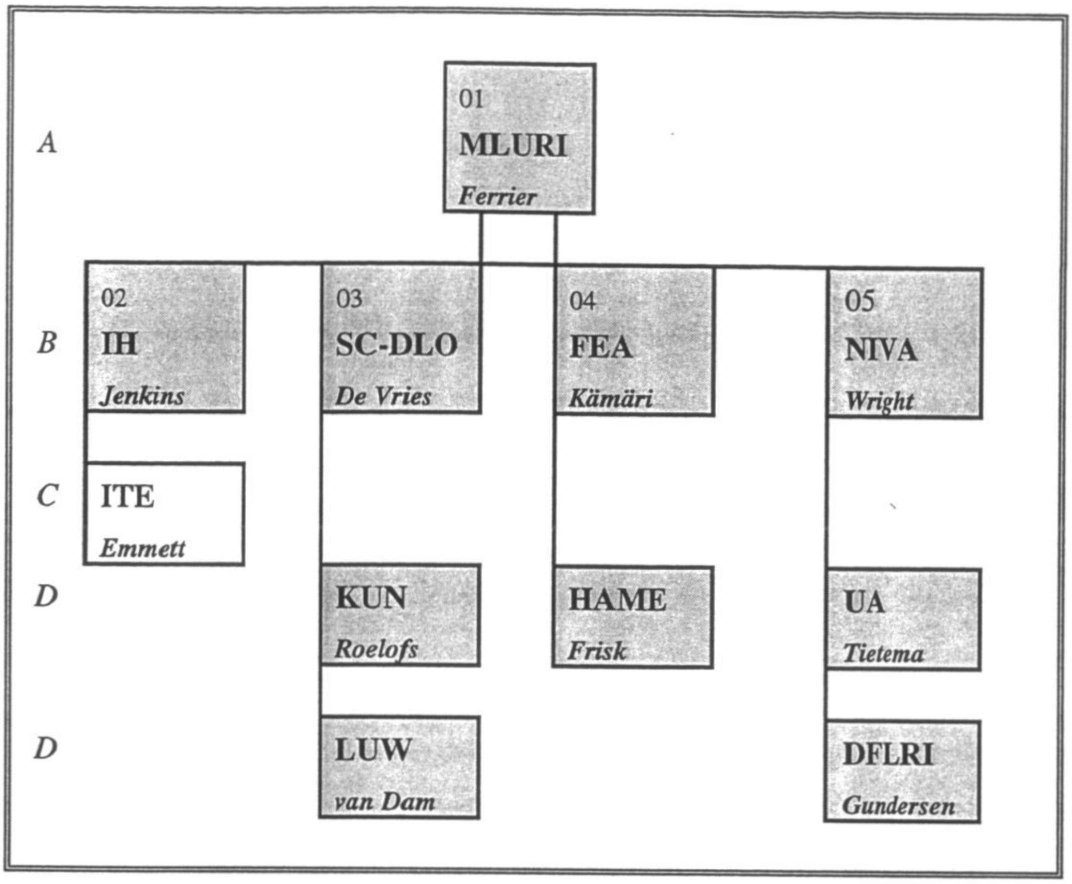


Table 5: The Partnership. Level A - represents the co-ordinator; level B - the partners; level C - collaborating sister Institutes; and level D - the sub-contractors of the relevant Partners.

Task	*Primary Involvement*	*Secondary Involvement*
Enhancement of the models		
SMART and NUCSAM	03	04
MAGIC/MAGIC-WAND	02	01, 05
Seasonality	02, 04	01
Standardised forest C/N dynamics	05	01, 02
Validation at specific sites		
Aber, Wales	02	01, 05
Siuntio & Nurmes, Finland	04	03
Risdalsheia, Norway	05	04
Speuld & Ysselsteyn, The Netherlands	03	05
Acid Waters Monitoring Network, UK	02	01
Regional applications		
Regional application to Wales	02	-
Landscape scale, SW Scotland	01	-
Extrapolation to river basin, Finland	04	-
Landscape scale, S Norway	05	-
National scale, UK	02, 01	-
Application to the Netherlands	03	-
Techniques for model regionalisation	01, 02, 03, 04 ,05	-
Continental scaling	03, 04	01 02, 05
International conference	01	02

Table 6: Partners involved in individual activities within the work packages, and those with secondary involvement.

Tasks	Y 1				Y 2				Y 3			
	1	2	3	4	1	2	3	4	1	2	3	4
Enhancement of the models												
SMART and NUCSAM	■	■	■	■								
MAGIC/MAGIC-WAND	■	■	■	■								
Seasonality			■	■	■	■						
Standardised forest C/N dynamics			■	■	■	■						
Validation at specific sites												
Aber, Wales		■	■	■								
Siuntio & Nurmes, Finland		■	■	■								
Risdalsheia, Norway		■	■	■								
Speuld & Ysselsteyn,the Netherlands	■	■	■									
Model comparison, the Netherlands			■	■	■	■						
Acid Waters Monitoring Network		■	■	■	■	■						
Model comparison at Risdalsheia							■	■	■	■		
Regional applications												
Techniques for regionalisation			■	■	■	■	■	■	■	■	■	
Regional application to Wales			■	■	■	■	■	■				
Landscape scale, SW Scotland			■	■	■	■	■	■				
Extrapolation to river basin, Finland					■	■	■	■				
Landscape scale, S Norway					■	■	■	■				
National scale, UK						■	■	■	■	■		
Regionalisation to the Netherlands				■	■	■	■	■	■	■		
Continental scaling							■	■	■	■	■	■
Planning International conference	■	■										
Hosting international conference								■				
Other												
Partnership meetings	■		■		■		■		■		■	
Production of EC reports				■				■				■

Table 7: Timing and duration of the activities of the work packages in DYNAMO.

7. The Partnership

Partner Number; 01
Laboratory; Macaulay Land Use Research Institute (MLURI)
Research leader; Dr. Robert C. Ferrier

Overall objective; To spatially integrate responses to land use change, deposition, and forest management at the ecotype, landscape and regional scales. Specifically;

(1) Use MERLIN model to identify generic responses and forest growth dynamics during full rotation of forests of given productivity.

(2) Incorporation of responses into parameterisation of MAGIC-WAND, for specific catchments in SW Scotland.

(3) Application of MAGIC-WAND to specific AWMN sites in SW Scotland to determine seasonal/monthly dynamics.

(4) Develop methodology for determination of dynamic changes occurring during the growth of different extents and ages of commercial plantations within the landscape and catchment scales, and model derived responses in a GIS environment.

(5) Development of landscape based model of the effect of forest management practices on the soil and water resource of S.W.Scotland, using multiple calibration techniques.

(6) To organise and host an International conference on the Regionalisation and scaling-up of dynamic models for the prediction of impacts.

Background; There is current requirement to determine where atmospheric deposition, land use and global change intersect with the landscape, and how these interactions will change in the future as a result of policy decisions on development, emissions control, and the modification of land use management. This assessment of policy at all spatial scales from individual catchments to the continental scale is dependent upon the application of appropriate modelling procedures. There is a requirement for the development of such processes based approaches which integrate over a range of spatial scales to determine landscape responses. The development of such models must be based on; a firm understanding of the processes involved; models that can summarise that information at an appropriate scale, and the expertise to apply these models in a regional framework. There is also a need for geographically explicit data on current conditions of environmental driving variables and response functions and the means to display current and future conditions in a mapped form (GIS).

Following the development of a landscape based model in Scotland, the applicability of this approach to other areas of Britain and Europe will be determined linking to the monte-carlo/stochastic approach of Partner 02. The inclusion of other land use types and forest of different productivities will be examined in conjunction with the

European perspectives of Partner 03 and the ECOFEE database of Gundersen, and to the development of global change distributed catchment and river basin models of Partner 04.

Experience; MLURI has a remit to undertake research, in the context of land use and resource management, with the objective of assessing the environmental, economic, and social impacts of land uses, and the consequences of changes resulting from factors and influences such as policy, management, and the effects of climate and pollution. The Institute is a lead centre for interdisciplinary fundamental and strategic research with emphasis on soils and pollution, and for developing methodologies to bring together and interpret information on land use. In particular, Dr. Robert C. Ferrier is a project leader with specific research responsibility for soil and water resource modelling, involving inter-disciplinary staff. Over the past decade his own research has focused on ecosystem biogeochemistry, and the application and development of hydrochemical models.

Relevant Publications;

FERRIER, R.C., Wright, R.F., Cosby, B.J. and Jenkins, A. 1995 Application of the MAGIC model to the spruce stand at Solling, Germany. Ecological Modelling, (in press).

FERRIER, R.C., Whitehead,P.G. and Miller,J.D. 1993 Potential impacts of afforestation and climate change on the stream water chemistry of the Monachyle catchment, central Scotland. Journal of Hydrology, 145, 453-466.

FERRIER, R.C., de Vries,W. and Warfvinge,P. 1995 The use of dynamic models for the assessment of critical loads of nitrogen. Developments since Lökeberg. UNECE Workshop on nitrogen deposition and its effects: critical loads mapping and modelling. Grange over Sands, Nov. 1994. (in press)

Macmillan, D.C. and FERRIER, R.C. 1994 A bioeconomic model for estimating the benefits of acid rain abatement to salmon fishing: A case study in south-west Scotland. Journal of Environmental Management and Planning, 37, 131-144.

Wright, R.F., Cosby, B.J. FERRIER, R.C., Jenkins, A., Bulger, A.J. and Harriman, R. 1994. Changes in the acidification of loch in Galloway, south-western Scotland, 1979-1988: The MAGIC model used to evaluate the role of afforestation, calculate critical loads, and predict fish status. Journal of Hydrology, 161, 257-285.

Partner Number; 02
Laboratory; Institute of Hydrology (IH), and Institute of Terrestrial Ecology (ITE)
Research leader; Dr. Alan Jenkins and Dr Bridget Emmett.

Overall Objective; To determine the response of soils and surface water to deposition and land use change at catchment and regional scale.

(1) To further develop the long term Nitrogen model MERLIN by application, validation and sensitivity analysis at the Aber experimental site in Wales and at intensively monitored catchments in the UK.

(2) To develop and apply regionalisation techniques for the application of MAGIC-WAND and MERLIN to survey data collected at regional scale in Wales.

(3) To incorporate seasonality, particularly with respect to hydrology, into MAGIC-WAND.

(4) To use the calibrated models to assess the implications of future changes in atmospheric deposition and land use at site specific and regional scale.

(5) To carry out a National scale application of MAGIC/MAGIC-WAND to the 1,200 sampled catchments of the UK Critical loads and atmospheric deposition for freshwaters database.

Background; The MAGIC-WAND and MERLIN models require detailed process and pool size information for calibration and validation. This is available for a few intensively studied and experimental manipulation sites. A clear need exists to extrapolate these models to regional scale so that nitrogen leaching and hydrochemical responses to potential land-use change and deposition reductions can be estimated for large areas of Europe. To achieve this, particularly given the emphasis on nitrogen dynamics in these models, an adequate technique for regionalising seasonal flow and soil moisture responses needs to be developed. Regionalisation of hydrochemical and flow response has long been a problem for hydrologists but now the development of GIS technology provides opportunity to reassess the problem.

The MAGIC-WAND model will be applied to intensively studied catchments in the UK (e.g. 22 sites in the UK DOE Acid Waters Monitoring Network) to determine major sensitivities. Application at regional scale will be to survey data collected in Wales using monte-carlo procedures. The resulting regional models will be used to assess future atmospheric deposition and land use change scenarios. The MERLIN model will be applied to the experimental manipulation catchment at Aber in Wales and to other sites in the UK with sufficient available data for calibration. Application at regional scale will utilise available water quality and land use databases for Wales and will employ monte-carlo procedures for calibration of the regional behaviour. Future response and model sensitivity to deposition and land use change will be assessed against the regional forest survey data. This work will be carried out in conjunction with colleagues at ITE Bangor (Dr. Bridget Emmett). The identification of a suitable process-based structure for simulating seasonal flow dynamics within the framework of the regional model will require assessment and application of existing hydrological models (e.g. TOPMODEL, IHACRES or some other model structure, existing or derived). The aim will be to provide flow proportioning between soil layers to enable monthly dynamic changes in soil moisture storage to be estimated. This will be applied to selected sites in SW Scotland where seasonal data is available (collaboration with partner 01). Finally, the development of methodologies for application of dynamic models at landscape, ecotype, and National scales will be undertaken in conjunction with all Partners.

Experience; IH has been at the forefront of hydrochemical and environmental modelling since its establishment as the only dedicated hydrological research laboratory in the UK in 1962. This proposal fits well with the evolving environmental research strategy at IH which reflects the central role of water within all aspects of natural ecosystems and the need to develop regional models for prediction and assessment. The Water Quality Systems (WQS) Section at IH, lead by Dr. Alan Jenkins, has primarily undertaken modelling research over the last 10 years. Recently several large modelling programmes, both national and international, directed at assessing acidic deposition, climate change and land use effects in catchment ecosystems have been initiated. Dr. Jenkins is the scientific co-ordinator of the EC CLIMEX programme. Dr. Bridget Emmett has worked in the field of nitrogen dynamics in forest ecosystems for 6 years and has access to experimental data and regional databases describing water chemistry, nutrient cycling and land use in Wales.

Relevant Publications;

JENKINS, A. and Cosby, B.J. 1989. Modelling surface water acidification using one and two soil layers and simple flow routing. In, Kämäri, J. et al. (Eds.) Regional Acidification Models, 253 - 267. Springer-Verlag, Heidelberg.

JENKINS, A., Whitehead, P.G., Musgrove, T.J. and Cosby, B.J. 1989. A regional model of acidification in Wales. Journal of Hydrology 116, 403 - 416.

Robson, A., JENKINS, A. and Neal, C. 1991. Towards predicting future episodic changes in stream chemistry. Journal of Hydrology 125, 161 - 174.

Morse, G., Eatherall, A., JENKINS, A. 1993. Predicting agricultural non-point source pollution using geographical information systems. J. Inst. Water Engineers and Scientists (In press).

EMMETT, B.A., Brittain,S.A., Hughes,S., & Kennedy,V. 1995. Nitrogen additions ($NaNO_3$ and NH_4NO_3) at Aber forest, Wales: II. Responses of trees and soil nitrogen transformations. Forest Ecology and Management,71, 61-74.

Partner Number; 03
Laboratory; Winand Staring Centre (SC-DLO)
Research leader; Dr. Wim de Vries

Overall objective; The aim of the contribution of the Winand Staring Centre (WSC) is the assessment of the effects of the simultaneous change in global climate and atmospheric deposition of S and N compounds on biogeochemical processes and soil (solution) chemistry at various scales (from sites to Europe). The various research tasks will consist of;

(1) Enhancement of models for application at a site and regional scale

(2) Validation of a detailed site scale model (standard model) and comparison of the long-term predictions with this model with a simplified, regionally applicable model

(3) Calibration/validation of the simplified model on a regional and continental scale

(4) Application of the simplified model on both scales, using available databases and appropriate interpolation techniques.

Background;

At SC-DLO soil acidification and nutrient cycling models have been developed for application at a site scale (NUCSAM; Groenenberg et al.,1995) and a regional scale (SMART2; de Vries et al,1989; Kros et al,1995). The role of SC-DLO will be to enhance these current modelling frameworks and to develop and apply methods for further regionalisation. The NUCSAM model will be validated at sites where soil (solution) monitoring data are available, either during a long time period or during a limited period during which , large changes took place. Examples of the latter sites are those where roof experiments have been performed such as the Speuld and Ysselsteyn sites in the Netherlands and the Gardsjon site in Sweden (NITREX sites) and the Risdalsheia site in Norway (CLIMEX site). This will involve close collaboration with Jan Roelofs at the Catholic University of Nijmegen, and Douwe van Dam at the Agricultural University of Wageningen. When the available observed data records are long enough the enhanced SMART2 model will also be validated at this scale.

Next to a validation at various sites, a comparison will be made between results of SMART 2 and, (i) large scale survey data on the soil (solution) chemistry below forests in a certain region (at the Winand Staring Centre, such data are available for some 150 - 200 soil profiles in the Netherlands (De Vries and Leeters,1994)) and (ii) observations on the pH and base saturation that are available for forest soils on an European scale (at Winand Staring Centre, such a forest soil database for Europe is presently available, including data for some 2,000 soil profiles for more that ten countries (Reinds 1994)).

Experience: Environmental protection is one of the task fields of SC-DLO. The proposed research thus fits within the research policy of the institute and experienced specialist are available. The scientists involved in the project are Dr. Ir. W. de Vries (Project leader at SC-DLO; Senior research officer), Ir. J.E Groenenberg (Research officer; specialised in modelling soil chemistry), Ir. J. Kros (Senior research officer; specialised in model calibration and uncertainty analysis), Ir G.J. Reinds (Research officer; specialised in coupling GIS to models) and Drs. C. van der Salm (Research officer; specialised in modelling soil hydrology). Several research projects within an international framework, especially in the EC, have been conducted by the Institute including research on nitrate leaching and long-term impacts of acid deposition on forests soils. There is a strong expertise in modelling on a large regional scale (Netherlands, Europe) and results from these studies have been published in several International journals, reports and proceedings of International workshops on critical loads of nitrogen and sulphur, air pollution, regional acidification modelling and vulnerability of soil and ground water to pollution (see also list of publications). Furthermore, results have been disseminated to the UN-ECE Task Force on Mapping critical loads.

Relevant publications;

KROS, J., P.S.C. Heuberger, P.H.M. Janssen and W. de Vries (1994). Regional calibration of a steady-state model to assess critical acid loads. In: J Grasman and G. van Straten (Eds.) Predictability and non-linear modelling in natural sciences and economics. Dordrecht, the Netherlands, Kluwer Academic Publishers : 541-553.

GROENENBERG,J.E. Kros,J., Salm, C. van der, and Vries,W. de 1995. Application of the NUCSAM model to the Solling spruce site. Ecological Modelling (in press).

VRIES, W. de, M. Posch and J. Kämäri (1989). Simulation of the long-term soil response to acid deposition in various buffer ranges. Water, Air and Soil Pollution 48:349-390

VRIES, W. de, G.J. Reinds, M. Posch, and J. Kämäri (1994b). Long-term soil response to acidic deposition in Europe. Water, Air and Soil Pollution 78:

VRIES,W de, Reinds, G.J., and Posch,M. (1994d) assessment of critical loads and their exceedance on European forests using a one-layer steady-state model. Water, Air, and Soil Pollution, 72, 357-394.

Partner Number; 04
Laboratory; Finnish Environment Agency (FEA)
Research Leader; Dr. Juha Kämäri

Overall objectives; The contribution of FEA will focus on the development of techniques to predict the impacts of global change on biogeochemical cycling, and to assess the regional implications of change. In particular;

(1) to adapt catchment-scale predictive models to include climate change effects,

(2) to evaluate these models using data from intensively-studied sites in Norway,

(3) to provide scenarios for the magnitude of climate change effect vs. the effects of changes in land use and deposition and to further develop regionalization techniques for the modelling approaches for regional assessments

Background; SMART (Simulation Model for Acidification's Regional Trends), a simple, dynamic process-oriented model based on the charge balance principle, has been developed in close collaboration of FEA and SC-DLO (DeVries et al. 1989, 1994). Recently, the nutrient cycle (litterfall, mineralisation and root uptake) and other temperature dependent soil processes (weathering rates, etc.) to the SMART have been included into the latest model version (SMART2) The SMART model is adapted to a seasonal (monthly) time step and a simple stream and lake water module, which uses the output of the soil module as input has been developed. Catchment hydrology will be included by linking the soil model with an existing catchment hydrology model (HBV/TOPMODEL).

In the first phase of the project the enhanced SMART model will be adapted for analysing land use and climate change impacts by testing and calibrating the model to data from the CLIMEX manipulation experiment, described in more detail by Partner 05 (NIVA). The adapted model is then furthermore applied to data from two intensively monitored sites in Finland. The emphasis for the applications in Finland is to assess the magnitude of climate change effects in comparison with effects of land use changes and deposition. The regional model applications in Finland will be focused on one river basin, River Kokemäenjoki in Western Finland. The conceptual regional model to be developed will consist of two components: a runoff model and a nutrient transport model.

Modelling at FEA will utilise both conceptual and stochastic regionalisation approaches. The conceptual regional approach will be developed by linking a current runoff model and a nutrient transport model, and this will be extrapolated to an entire river basin. The stochastic regionalisation techniques in which model runs are selected from input and parameter distributions for specific regions will be bases on available survey data, and will incorporate the statistically based lake survey to be conducted in the fall of 1995 in Finland, Norway, and Sweden.

Experience; FEA is the only governmental research and development institute located within the administration of the Ministry of Environment. Funding for research at FEA comes partly directly from state budget, partly from the Ministry of Environment, and partly from various other sources on separate research contracts. FEA has the responsibility of carrying out environmental research and monitoring, publishing and disseminating the results, and maintaining the appropriate information systems. From a strong base in water research, activities have expanded in recent years to include research on soils, wastes, chemicals, and conservation ecology. There is a strong emphasis at FEA to provide scientific support to the decision making processes concerning large scale environmental problems like air pollution, climate change, and effects of agriculture and silviculture on aquatic and terrestrial ecosystems in Finland. FEA employs nearly 400 people, more than 100 of which are university educated scientists involved with environmental studies (including air pollutant and climate change effects). This enthusiastic research group has long a tradition in large scale regional surveys, modelling environmental processes and utilising representative regional data sets in regionalising site-specific models, and applying environmental models on a large regional scale.

Relevant Publications;

De Vries,W., Posch,M., and KAMARI,J. 1989. Modelling time patterns of soil acidification for various deposition scenarios. In: Kämäri et al. Eds. Regional Acidification Models: Geographical Extent and Time Development, Springer Verlag, New York. pp. 129-150.

Posch,M. and KAMARI,J 1990. Modelling regional acidification of Finnish Lakes. In: Kämäri et al. Eds. Impact models to assess regional acidification. Kluwer Academic publications, Dordrecht, The Netherlands, pp. 145-166.

De Vries,W., Posch,M, Reinds,G.J. and KAMARI,J. 1994. Simulation of soil responses to acidic deposition scenarios in Europe. Water,Air, and Soil Pollution, 78, 215-246.

Bilaletdin,F., Kallio,K., FRISK,T., Vehvilainen,B., Huttunen,M., and Roos,J. 1994. A modification of the HBV model for assessing phosphorus transport from drainage area. Water Science and Technology, 30, 179-182.

Ahtiainen,M. 1992. the effect of forest clear-cutting and scarification on the water quality of small brooks. Hydrobiologia, 243/244, 465-473.

Partner Number; 05
Laboratory; Norwegian Water Research Institute (NIVA)
Research leader; Dr. Richard F. Wright

Overall objective; Within the overall project, NIVA has the following role;

(1) to provide data for the site at Risdalsheia (RAIN and CLIMEX projects)

(2) to apply and evaluate MAGIC and MERLIN at Risdalsheia

(3) to supply regional data on vegetation, soils, acid deposition and climate for the region of southernmost Norway

(4) to undertake a regional application of MERLIN in the Veluwe, NL. (as part of a sub-contract to A. Tietema, University of Amsterdam)

(5) to apply MAGIC-WAND to scale up to the region

(6) to use the ECOFEE database from forested stands and catchments to scale-up to European forests

(7) to link DYNAMO with the IGBP-GCTE modelling activities at the LEMA centre (Long-term Ecological Modelling Activity) at the University of Virginia, USA (through collaboration with B. Jack Cosby).

Background; NIVA will use field data from intensively-studied and experimentally-manipulated catchments at Risdaslheia for the application and evaluation of site-specific models. These will then be expanded to regionalized models. NIVA has direct access to such data through participation in several major projects, and especially projects such as RAIN (Wright et al. 1993), NITREX (Wright et al. 1995), and CLIMEX (Jenkins et al. 1993) in which entire catchment-ecosystems are experimentally manipulated. NIVA has played this role previously in the development and regionalization of MAGIC (Cosby et al. 1985, Wright et al. 1991), and MERLIN (Cosby et al. in prep.). A sub-contract will be let to Albert Tietema, University of Amsterdam (UA), for assistance in application of models for nitrogen dynamics. a second sub-contract will be let to Per Gundersen, Danish Forest and Landscape Research Institute (DFLRI), to evaluate modelled results from individual sites and regions with respect to the ECOFEE database.

Experience; NIVA is Norway's largest and leading research organisation dealing with freshwater ecosystems and water pollution. Catchment manipulation studies and modelling have been central activities at NIVA for many years. The effects of acid deposition, land-use and climate change on aquatic ecosystems are important and priority research fields both at NIVA. The project leader Dr. Richard Wright has 20 years experience in hydrochemical research including field studies, catchment-scale experiments and modelling. He was project manager for the RAIN (Reversing Acidification In Norway) experiment (1983-94), participant in the EU-funded CLIMEX (Climate change experiment), and scientific co-ordinator for the EU-funded project, NITREX (Nitrogen saturation experiments). Dr. Tietema (UA) is an expert in soil processes, participates in the NITREX project, and has applied models at Speuld. Dr. Gundersen is an expert in nitrogen cycling in forests and has complied a European forest database as part of a project supported by the Nordic Council of Ministers.

Relevant publications;

WRIGHT, R.F., B.J. Cosby, M.B. Flaten, and J.O. Reuss (1990) Evaluation of an acidification model with data from manipulated catchments in Norway. Nature 343: 53-55.

WRIGHT, R.F., B.J. Cosby, and G.M. Hornberger (1991) A regional model of lake acidification in southernmost Norway. Ambio 20: 222-225.

WRIGHT, R.F., E. Lotse, and A. Semb (1993) RAIN project: results after 8 years of experimentally reduced acid deposition to a whole catchment. Can. J. Fish. Aquat. Sci. 50: 258-268.

TIETEMA, A., and C. Beier. 1995. A correlative evaluation of nitrogen cycling in the forest ecosystems of the EC projects NITREX and EXMAN. Forest Ecol. Manage. 71: 143-152.

GUNDERSEN, P 1991. Nitrogen deposition and the forest nitrogen cycle: the role of denitrification. Forest Ecol. Manage. 44: 15-28.

ITE – @ 14 rates ~~costs~~.

Staffs T+S.

Send cost statements

8. Financial information

Costs for 3 years (1 October 1995 - 30 September 1998). Units: 1000 ECU

	01 MLURI	02 IH	03 SC-DLO	04 FEA	05 NIVA	*TOTAL*
Personnel (man-months)	252 (42)	~~137~~ ~~122~~ ~~102~~ ~~(51)~~ ? 100	252 (45)	192 (61)	101 (30)	***934*** *(229)*
Travel and subsistence	27	20	10	17	20	***93***
Durable equipment	10	0	4	15	0	***29***
Consumables	5	0	0	6	4	***15***
Computing services	10	~~20~~ 9	20	0	0	***50***
Other costs	22	0	10	40	82	***154***
Overhead	126	~~175~~ ~~185~~ 140	134	100	113	***648***
TOTAL (i) % requested	**452** 50%	~~**352**~~ 260 50%	**430** 50%	**370** 50%	**320** 50%	***1,924*** *50%*
TOTAL (ii)	~~**226**~~ 180	~~**176**~~ 130	~~**215**~~ 130	~~**185**~~ 130	~~**160**~~ 130	~~***962***~~ 700

Original 20/11/97 – 31/11/94

Overall cost statement to end May.

TOTAL PROJECT BUDGET REQUESTED FROM EC : ~~**962,000 ECU**~~ 700

13,000

Note: *Other costs*

01 MLURI ; Cost associated with the organisation and hosting of an International conference.

03 SC-DLO; Subcontracts to J. Roelofs KUN, and D. van Dam LUN.

04 FEA; Subcontract to T. Frisk, HAME Regional Environment Centre,Tampere.

05 NIVA; Sub-contracts to A. Tietema, UA, and P. Gundersen, DFLRI.

9. Exploitation plans.

Results of this research will be published in peer-reviewed scientific journals to maintain scientific credibility, and therefore exploitable for International policy support. Reports from this work will also be published to ensure accountability and written in a way as to be easily interpretable and usable by policy decision makers. Results of this proposal will also be disseminated to various bodies within the EU and UN/ECE for International collaboration.

10. Ongoing projects and previous proposals.

A similar proposal "Development and Application of Regionalisation Techniques to Assess Effects of Global Change on Forest Soils and Surface Waters" was submitted in July 1993 to the ENVIRONMENT Programme (proposal no. PL931915), received a 3 rating, but was not funded. DYNAMO includes the major initiatives of this previous proposal, except that Macaulay Land Use Research Institute (MLURI) is now co-ordinator, and sub-contracts for specific tasks involve, the University of Amsterdam, Catholic University of Nijmegen, Agricultural University of Wageningen, Danish Forest Research Institute, and the HAME Regional Environment Centre, Tampere.